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Meat outside the freezer: Drying, smoking, salting and sealing meat in fat at an Epipalaeolithic *megasite* in eastern Jordan

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ABSTRACT

Even though pivotal for understanding many aspects of human behaviour, preservation and storage of animal resources has not received great attention from archaeologists. One could argue that the main problem lies in the difficulties of demonstrating meat storage archaeologically due to the lack of direct evidence. This paper represents an attempt to refine zooarchaeological methods for the recognition of meat preservation and storage at prehistoric sites. Drawing on the faunal assemblage from Kharaneh IV, an Early/Middle Epipalaeolithic aggregation site in eastern Jordan, this study demonstrates that a combination of taphonomic and contextual analyses alongside ethnographic information may indeed lead archaeologists to insights not directly available from the archaeological record. The empirical evidence presented here contributes to the archaeological visibility of meat preservation and storage, providing a clearer concept of the nature of these practices in pre-agricultural societies.

1. Introduction

> "*There are a number of behavioural domains that for all practical purposes remain archaeologically invisible, or at least frustratingly intractable, despite the fact that we know they are present, even universal, among modern foragers*" (Speth 2017: 45).

Changes in the composition of human diet at approximately 2.5 million years ago have been linked to the evolution of many hominin traits, including gut reduction and evolution of large size brains (Aiello and Wheeler, 1995; Ruff et al., 1997), sexual division of labour (Kuhn and Stiner, 2006), prosociality, pair-ponding (Crittenden and Zes, 2015) and exceptionally long adult life (Kaplan et al., 2000). In addition, thermal processing of plant and animal resources had substantial evolutionary significance as it released "a treasure trove of calories unavailable to other animals," (Pollan, 2013: 6) increased digestibility (Stahl, 1984, 1989: 181–182; Wrangham, 2009), minimized the pathogens growing on meat (Carmody and Wrangham, 2009) and opened up unlimited possibilities for new cultural and social rules (Barkai et al., 2017; Wright, 2004: 33). On the top of these developments, the ability to preserve plant and animal resources has been a cornerstone in the successful survival of humans, providing increased socio-ecological resilience under environmental and climatic stress (Balbo, 2015: 305).

Although often taken for granted by consumers in the modern world, maintaining a reliable food supply has always played a major role in the history of our species. The realization of the effects of seasonality on plant and animal resources led our ancestors to experiment with numerous technological innovations in food processing, preservation, storage and transportation (Hammond et al., 2015: 758), but the roots of these innovations and their role in shaping human history have received limited attention from archaeologists (but see: Cunningham, 2011; Divale, 1999; Soffer, 1989; Speth, 2018).

In the prehistoric context of the Middle East, much research has been dedicated to the large-scale storage of grain and its significance for the emergence of the first sedentary communities of the Neolithic (Kuijt, 2008, 2009, 2015; Kuijt and Finlayson, 2009). At the same time, small-scale storage of meat and other animal nutrients remains a relatively unexamined component of the mobile life-ways of Late Pleistocene hunter-gatherers who occupied the Southern Levant during the Late Upper Palaeolithic to Middle Epipalaeolithic (ca. 28–14.4.ka cal. BP). This gap in research, extended also in later periods, is mainly related to the practical difficulties of recognizing meat storage directly in the archaeological record such as in the form of dried strips of meat that

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do not preserve archaeologically except under exceptional conditions (i.e., Pendlebury, 1951: 169-170). Ethnographic accounts of both hunter-gatherers and farmers provide evidence for a wide range of storage methods that occur off-site, throughout the placement of large and small caches of resources in areas away from sites where archaeologists stand a chance of finding them (Cunningham, 2011; Morgan 2008, 2012; Stopp, 2002: 319-320). In addition, dried meat and fat are frequently mixed together and used by many hunter-gatherer societies as portable sources of nutrition (Stopp, 2002), usually placed in perishable containers including animal guts and paunches, bark, rawhide and hair bags, animal skin, plant fibre and animal dung that have little potential to be preserved archaeologically (Peña-Chocarro et al., 2015). In any event, the likelihood that stored food will be found in archaeological features is particularly low, partly due to taphonomic factors, but also because a storer's intention is to re-access and presumably consume stored food (Bettinger, 1999); therefore other methods are needed to infer storage (i.e., Kent, 1999; Rowley-Conwy and Zvelebil, 1989: 40). Many theoretical models of storage systems have been proposed (Bettinger, 2009:47–57; Binford, 1980; Kelly, 1995, 2013; Testart, 1982; Woodburn, 1980), however, these are mostly abstract and rarely employ empirical evidence from actual archaeological features (although see: Morgan, 2008, 2012).

With a specific focus on Kharaneh IV, a multi-component Early to Middle Epipalaeolithic aggregation site in the Azraq Basin, Jordan, this paper aims to refine methods for identifying meat and fat preservation and storage at such prehistoric sites. The specific ecological conditions and marked climatic and vegetational seasonality of eastern Jordan, taken together with evidence for high dependence on gazelle hunting and intensive carcass exploitation, provide good opportunities to move beyond the procurement questions that have been widely addressed for the Levantine Epipalaeolithic (i.e., Bar-Oz, 2004), to explore *inter alia* the possibility that meat preservation and storage were practiced at the site. In this paper, we employ zooarchaeological and taphonomic data, and contextual analyses of faunal skeletal elements from deposits around a series of postholes at Kharaneh IV, alongside relevant ethnographic information, to provide empirical evidence that meat preservation through drying was practiced at the site. The study makes a methodological contribution to the archaeological detection of meat preservation and storage, particularly for pre-agricultural societies.

In the sections below we highlight the multidimensionality of food storage in hunting and gathering societies. Drawing on a wide range of available ethnographic data, we provide an overview of storage potentials of different animal resources, focusing on meat and fat. Although ethnographic information can be used as a framework for reflecting on the wide diversity of potential past practices, we acknowledge that prehistoric storage practices may have significantly differed from our comparative cases. For this reason, ethnographic analogy is not used in a uniformitarian way, but it is rather used in order to demonstrate that there are many different ways to preserve and store animal resources as well as many different ways of being a hunter-gatherer (Cunningham, 2011; Hather and Mason, 2002: 5; Zvelebil and Fewster, 2001: 153). As Finlayson has recently highlighted "what appears to be the real shared characteristic between present and past hunter-gatherer societies is their huge capacity for adaptation, resilience, flexibility, and consequent variation in life-ways" (Finlayson, 2017: 63).

2. The multidimensionality of food storage in hunter-gatherer societies

A rich body of archaeological and anthropological literature on storage already exists, with case studies varying in theoretical and methodological approaches, periods and places (i.e., Balbo, 2015; Bettinger, 1999; Cunningham, 2011; Ingold, 1982, 1983; Keeley, 1988; Kelly, 1995, 2013; Morgan, 2008, 2012; Soffer, 1989; Testart, 1982; Woodburn, 1982). Storage is a key activity for securing resources for the periods of food shortage and a risk reduction strategy for coping with the uncertainties that characterize subsistence, e.g. seasonal and annual climatic fluctuations, natural hazards, and all sources of variability that may affect food quality and availability (Binford, 1978, 1980; Halstead and O'Shea, 1989; Jochim, 1981; Keeley, 1988; Kelly, 1995, 2013; Testart, 1982; Winterhalder, 1986). At its most basic, storage extends the period of time during which consumption is possible (Binford, 1990: 140-142) and it is also an effective way of avoiding food waste by managing the excess of production (Ikram, 1995: 283; Stopp, 2002), especially where there are demographic restrictions and the human group cannot fully harvest a catch (Binford, 1978; Kelly, 1995, 2013). Storage can also occur for a variety of other reasons, including aggregation of resources for communal purposes such as large-scale feasting events (i.e., Kuijt, 2009), calendrical rituals as well as for trade and exchange.

Preservation and storage of food for later consumption was originally thought to be an exclusively agrarian practice (Adams, 1966). An appreciation for its importance within hunter-gatherer communities has grown since the 1980s (Binford, 1980; Ingold, 1982, 1983; Rowley-Conwy, 1999, 2001; Rowley-Conwy and Zvelebil, 1989; Testart, 1982; Woodburn, 1980, 1982). Food storage and mobility have been integral elements in Binford's (1980) ecological forager-collector model, which highlighted the ecological parameters that bring storage into practice, including seasonality, resource structure, availability and length of the growing season. Binford (1980, 2001) saw storage as an overwintering adaptive strategy when he tried to determine why some hunter-gatherers store and some others don't. From his point of view foragers with sufficient population density who live in seasonal, mid-latitude settings take resources in bulk during summer, spring and fall and rely upon these stores during the winter. The problem with taking Binford's adaptive approach is that the environment largely determines human behaviour and decision-making, leaving people reacting within the constraints of their environment (Cunningham, 2001: 139). Moreover the reduction of storage to the single dimension of risk reduction is unfortunate since both hunter-gatherers and farmers store food and other things for many reasons other than risk reduction. They also store resources socially (Halstead and O'Shea, 1982), an argument that has frequently been made in the anthropological literature of the Ju/'hoansi Bushmen, including the famous *hxaro* (Smith, 2001).

James Woodburn (1982) divided hunter-gatherer societies on the basis of absence or presence of food storage: the immediate-return and the delayed-return systems. However, Woodburn (1980: 99) does suggest that nomadic populations who use immediate-return systems may also practice small-scale portable storage. A characteristic example are the San (Bushmen) of Kalahari who have become world famous as "models" of prehistoric "immediate-return foragers", and their methods of making biltong (strips of jerked or dried meat) are widely documented in both the scientific and popular literature (i.e., Hitchcock, 2006).

In a very influential paper, Alain Testart (1982) pinpointed the significance of food storage in a hunting and gathering society, specifically sedentary groups, proposing that ecological conditions (resource abundance and seasonality) as well as technical conditions (food getting and food storage techniques, see Testart, 1982: 523) facilitated the keeping of large stocks of food which resulted in social behaviours and population densities previously considered exclusive to agriculturalists (for a more recent discussion see also: De Salieu and Testart, 2015).

Storage has been considered incompatible with mobility due to problems of access and transportation of stored resources (Hayden, 1981: 387; Rowley-Conwy and Zvelebil, 1989: 45–47; Sahlins, 1972: 32). However, a connection between storage and sedentism is neither ethnographically nor historically documented. Ingold (1983:560) was among the first to propose that *storage, even on a substantial scale, is by no means incompatible with nomadic movement* (Ingold, 1982, 1987; see also Cunningham, 2011; Stopp, 2002) while Soffer (1989) argues that Upper Palaeolithic storage capacity on the Central Russian Plain

increased twofold over the course of the Last Glacial Maximum while seasonal mobility remained high" (Soffer, 1989: 722). Storage does not necessarily involve architectural structures and immovable facilities such as those found in Neolithic and subsequent periods; it can also exist in several other forms such as portable food items (Cunningham, 2011; Stopp, 2002) or strategically placed caches (Cunningham, 2011; Henrikson, 2003; Morgan, 2008, 2012; Stopp, 2002). These types of storage may have been particularly important – and perhaps easier to achieve – to hunter-gatherers living in less ecologically diverse areas of the Southern Levant; in such areas one or two resources (i.e. cereals, gazelle) were seasonally abundant and "could be gathered en masse while available and stored on a large scale […] thus becoming the staple food year-round" (Testart, 1982: 523).

At last, it should be highlighted that storage is a universal, multi-dimensional and multi-state phenomenon, which varies according to a wide range of internal and external factors, including economic, social, demographic, environmental and historical. Ethnographic research has demonstrated that there is a great deal of variation in the form, scale and function of food storage, depending on specific geographical, cultural and ecological settings (Angourakis et al., 2015; Morgan, 2012: 715). Recognizing this variability provides a way of moving beyond binary oppositions such as foragers and collectors, immediate and delayed-return systems, or egalitarian and non-egalitarian groups that may or may not exist ethnographically and archaeologically and, instead, allows us to assess the roles ecology, mobility, group size, and social distinctions played in the development of different storage behaviors in pre-agricultural societies.

2.1. Meat and fat as portable sources of nutrition

Humans are not the only species who store food. Hoarding or caching occurs in 12 of 170 families of birds, and in 19 of 120 families of mammals (Sherry, 1985: 153). However, humans are the only species who consistently use technology in order to delay the consumption of resources. In this paper, the focus is on two traditional methods of animal carcass preservation, namely meat drying (including smoking and salting) and preserving meat in fat. Other meat preservation techniques such as fermentation and freezing might have also been available to pre-industrial societies, (i.e., Boethius, 2016; Speth, 2017).

2.1.1. Meat drying

Drying is regarded as one of the oldest food preservation techniques available to humankind (Akhtar and Pandey, 2015). An analysis of energy use by Neanderthals in Northern Europe during the mild Eem interglacial period (≈125 ky BP) led Sørensen (2009) to suggest that during summer warmth, transport of meat back to the base settlement would not be possible without some technique to avoid meat rotting. He further noted that the only likely technique available to Neanderthals was meat drying (Sørensen, 2009: 2203–2204). Following the same logic, meat drying is very likely to have been a normal part of the carcass processing sequence at many "specialized-hunting" Neanderthal sites such as Les Pradelles in Southern France (Costamagno et al., 2006), otherwise much of the meat obtained from communal hunting expeditions would have gone to waste. The recent discovery and analysis of a 400,000 year-old bison kill/processing location at Atapuerca in northern Spain (Rodriguez-Hidalgo et al., 2015) makes it likely that meat-drying dates well back into the Middle Pleistocene, and that it possibly predates the appearance of *Homo sapiens* in Europe.

The most thorough description of the labour and time constraints involved in properly drying meat is offered by Henry and Karyn Sharp (2015), scholars with extensive knowledge of the Denesuline (also known as Chipewyan), a boreal forest-tundra interface hunter-gatherer group inhabiting the Subarctic region of Canada (Sharp and Sharp, 2015: 43–45). Meat drying can be achieved with exposure to the sun and wind by hanging strips of meat over tree branches, with pieces of meat placed flat on animal skins in open areas or on constructed drying facilities, (i.e., racks and wooden scaffolds). A crucial consideration for successful dehydration of meat is a dramatic reduction in moisture in order to preclude the possibility of microbial growth, thus this preservation method is more popular in areas characterized by hot and dry climate (Ikram, 1995: 283). Meat drying is a labour-intensive and time-consuming process that may well preclude further hunting for two to three days or more until the processing is completed (Speth, 2018: 194). Even in the arid Kalahari Desert, more than a day and a half are required to dry the strips sufficiently to prevent the onset of bacterial spoilage (Schulz and Hammar, 1897: 23). In addition, successful drying demands a great deal of skill, work, and experience. In order to be dried quickly and evenly, the meat must be carefully sliced into uniformly thin strips to increase surface area relative to volume. Slicing the meat to the proper thickness is a tedious process even for a skilled butcher (Weltfish, 1977: 217). As it dries, the meat must be protected from rain dew and predator-scavengers, including rodents, foxes, cats, bears, wolves, wolverines, and aerial pests such as ravens and jays (Speth, 2018: 195).

A notable advantage of drying against other food preservation methods is that it facilitates transportation and makes handling easier by reducing size, weight, and risk of microbial contamination (Akhtar and Pandeay, 2015: 22). Drying reduces the weight of the cut to about a third to a fifth of its original wet weight, the amount depending on other factors such as fat content and how long the meat is allowed to dry (Wheat, 1972). Thus, Soffer (1989: 722) pinpoints that dried food increase portability, allowing groups to retain high levels of mobility.

Based on ethnohistoric documents from the 17th to 19th centuries, Marianne Stopp (2002) provides a detailed inventory of meat and fat preservation techniques and their associated by-products that are available to the semi-sedentary groups of the north-eastern subarctic: the Innu and Inuit of the Labrador-Quebec peninsula and the Beothuk of the island of Newfoundland (Stopp, 2002: 307, her Table 1). These include caribou meat cut into long strips and dried or smoked over fire in tents, meat shredded and pounded to a paste for further mixing with fat or for the preparation of stews (Leacock and Rothschild, 1994: 103), dried meat wrapped in parchment-like subcutaneous tissue (Turner, 1979: 114–116) and meat powder (Cabot, 1912: 228). Dehydrated portable foodstuffs prepared for the long journeys included *uinastikai*, a

Table 1
Friesen's (2001: 320, Table 2) adaptation of Binford's (1978) Drying Utility Index (DUI) for caribou (*Rangifer tarandus*). Bold area shows the anatomical regions with the highest Meat Drying Index (MDI) values and the highest potentials to be successfully dried.

Element	Gross weight	Bone weight	Brain or marrow weight	% Brain or marrow weight	Meat weight	Meat drying index
Skull	1397.1	460.1	361.8	100.0	575.2	1.9
Mandible w/ tongue	1778.1	178.1	8.7	2.4	1591.3	66.4
Mandible w/ out tongue	768.1	178.1	8.7	2.4	581.3	56.2
Atlas-axis	630.2	106.0	0	1.0	524.2	88.2
Cervical 2–7	**2112.2**	**207.0**	**0**	**1.0**	**1905.2**	**186.7**
Thoracic	**2789.6**	**357.0**	**0**	**1.0**	**2432.6**	**311.3**
Lumbar	**1940.0**	**234.0**	**0**	**1.0**	**1706.0**	**205.8**
Pelvis	**3175.2**	**644.2**	**9.5**	**2.6**	**2521.5**	**196.8**
Rib	**3687.4**	**1037.0**	**0**	**1.0**	**2650.4**	**745.4**
Sternum	**3628.8**	**207.0**	**0**	**1.0**	**3421.8**	**195.2**
Scapula	2398.4	103.0	4.0	1.1	2291.4	89.5
Humerus	1661.3	174.9	30.0	8.3	1456.4	18.5
Radius	918.5	164.0	28.4	7.9	726.1	16.4
Metacarpal	374.2	106.2	16.6	4.6	251.4	15.5
Femur	5342.3	202.9	41.1	11.4	5098.3	17.0
Tibia	1532.0	222.1	50.6	14.0	1259.3	13.0
Metatarsal	754.1	173.1	40.3	11.1	540.7	11.2
Phalanx	294.8	108.0	3.2	1.0	183.6	67.3

mixture of blood and partially digested stomach contents (lichens) of caribou placed in a caribou oesophagus (Tanner, 1947: 684) and *wutu't*, a mixture of dried meat and suet placed in leather bags or inside the animal's bladder (Tanner, 1947: 684).

One potentially useful approach to the zooarchaeological study of meat preservation through drying is Binford's concept of the Drying Utility Index (DUI; Binford, 1978) which predicts which body parts and carcass portions with attached bone will be selected for storage by drying.

While working with the caribou dependent Alaskan Nunamiut Eskimo, Binford (1978) highlighted that meat drying imposes special constraints on butchery and that carcass portions would be treated differently if they were destined to be dried rather than immediately consumed. However, and due to its complex tabulations, zooarchaeologists were discouraged from using Binford's DUI; yet a modified and simplified version proposed by Friesen (2001), known as the Meat Drying Index (MDI) might hold the key for addressing questions related to the archaeological visibility of meat drying at hunter-gatherers' settlements (i.e., De Nigris and Mengoni-Goñalons, 2005; Friesen and Steward, 2013). Based upon Binford's data for caribou, Friesen (2001) proposed that the skeletal elements of the thorax (thoracic vertebrae, ribs, sternum), adjacent axial regions (cervical, lumbar), and pelvic bones have the highest potentials to be successfully dried and that these are usually the animal body portions to be put on drying facilities (Table 1). The successful application of the MDI to gazelle bone samples from Kharaneh IV, demonstrates its potential to be used in other temporal and geographical contexts.

2.1.2. Fat as a portable source of nutrition

The exploitation of animal fats by hunter-gatherers is a well-documented strategy in the ethnographic and archaeological records (i.e., Bar-Oz and Munro, 2007; Binford, 1978; Kent, 1993; Manne, 2014; Outram, 1998, 1999, 2000; Speth, 1987, 1991; Speth and Spielmann, 1983) and there are many cases in which fat was the primary goal of the hunt while meat was only a by-product (Loring, 1997: 197). Dietary fat can be obtained from a number of different sources, including oily nuts, fish and dairy products as well as from the adipose tissue of animals (subcutaneous fat). However, the most obvious and reliable sources of fat can be found within mammalian long bones; these are bone marrow and bone grease.

An important characteristic of animal fats is their role in the long-term preservation of plant and animal resources. The process of cooking meat in fat for a long period of time and in low temperatures, renders rough cuts tenderer and allows meat to be preserved in layers of fat for prolonged periods of time as long as the mixture is kept in a cool place. This natural method of meat preservation is still very popular with Cypriot *zalatina* (ready-to-eat pork meat cuts preserved in layers of fat; see: Patapiou and Lazarou, 2013) being one of the most characteristic examples. Rendered fat can be stored either in solid cakes or as a liquid in skin bags (Leechman, 1951; Vehik, 1977). Among the Innu, storable marrow fat was consumed as a staple travelling fare in the form of a fat pudding (Davies and Johnson, 1963) and hardened fat was used to preserve caribou meat or mixed with shredded meat and berries and stored in skin bags (Leacock and Rothschild, 1994) or in a caribou oesophagus (Speck, 1935). Fat was also an important component for the preparation of pemmican (a very nutritious foodstuff), made from dried bison meat, tallow and dried fruits. If stored properly, pemmican could be preserved for a couple of months or even years (Loring, 1997).

In this paper, we focus specifically on bone processing for marrow and grease which can be inferred from the nature of fragmentation and breakage of faunal skeletal remains. Bone fat exploitation is an activity that is frequently cited as a causal explanation for the nature of many fractured and fragmented bone assemblages in prehistory, and zooarchaeological assemblages have frequently been studied as evidence of bone fat exploitation (Bar-Oz and Munro, 2007; Munro and Bar-Oz, 2005; Outram, 1998). Archaeological identification of bone marrow extraction by humans can be attested through the intensive fragmentation of diagnostic long bones, and from the morphological study of fragmented long bone diaphyses (Outram, 1998; Villa and Mahieu, 1991), whilst grease rendering activities can be demonstrated through the intensive fragmentation or underrepresentation of diagnostic cancellous bone, including ribs, vertebrae, and epiphyses. The extraction of bone grease differs from marrow in that it requires boiling technology, thus, fire cracked rocks (FCR) and subterranean pits at archaeological sites, may provide secondary evidence for grease exploitation practices (Binford, 1967; Munro and Bar-Oz, 2005: 225). Recent excavations at the Mitchell Prehistoric Indian Village, an Initial Middle Missouri site in Mitchell, South Dakota have revealed a large, clay-lined feature filled with fractured and fragmented bison bones. Fracture and fragmentation analysis, along with taphonomic evidence, suggests that the bones preserved within the feature represent evidence of prehistoric bone marrow and bone grease exploitation (Karr et al., 2015).

Several taxa have been experimentally butchered to estimate the caloric value of their bone marrow (Bar-Oz and Munro, 2007; Binford, 1978; Blumenschine and Madrigal, 1993; Edwards and Steel, 2011; Lupo, 1998; Madrigal and Capaldo, 1999; Outram and Rowley-Conwy, 1998) and these studies provide valuable insight into the intensity of carcass use by humans at different time periods. Manne (2014: 121), for example, suggested that intensive exploitation of bone grease during the Early Upper Palaeolithic at the site of Vale Boi in Portugal may have been linked to the fact that fats provide a critical source of highly-portable, energy-rich food, easily transported on long-distance journeys, and may have been used to maintain links with distant groups to the east and south.

3. The site of Kharaneh IV

Covering an area of 21,000 m^2 the archaeological site of Kharaneh IV (19.9–18.6 ka cal. BP.; Maher et al., 2011; Richter et al., 2013) is situated at the western edge of the Azraq Basin (Fig. 1) and it is one of two substantial Early to Middle Epipalaeolithic open air sites in Southwest Asia (Garrard and Byrd, 1992, 2013; Richter et al., 2013). The other site, Jilat 6, is located 20 km south to Kharaneh IV and it is estimated to be approximately 19,000 m^2 (Garrard and Byrd, 2013). Kharaneh IV was initially surveyed by Andrew Garrard and Stanley Price in the 1970s and small test excavations were conducted in the 1980's by the Jordanian archaeologist Mujahed Muheisen who excavated three areas totaling ~15 m^2 (Muheisen, 1988; Muheisen and Wada, 1995). Renewed research since 2008 by the Epipalaeolithic Foragers in Azraq Project (EFAP), a multidisciplinary research programme interested in reconstructing hunter-gatherers' adaptations during the final Pleistocene and early Holocene transition, has revisited this important site through new excavations, accompanied by intensive palaeoenvironmental and geoarchaeological research (Jones and Richter, 2011; Jones et al., 2016, 2017). EFAP excavations focus on two occupation areas: Area A and Area B (Fig. 2). A deep sounding in Area A indicates that there were three stratified occupational phases at the site, two Early Epipalaeolithic and one Middle Epipalaeolithic. The earliest phase is characterized by the use of the microburin technique, and the presence of microgravettes, pointed and backed bladelets, and scalene bladelets, as well as the use of bipolar backing. The second phase continues to see the use of the microburin technique, with the intensive use of oblique truncated and backed bladelets. The third phase of the site is characterized by the dominance of geometric microliths in the lithic assemblage, including trapeze-rectangles and unbacked trapezes, along with other geometric forms in lower proportions (Macdonald et al., 2018). An abundance of charcoal taken from both areas suggests that the site was occupied between 19830 and 18600 cal BP (at 95% confidence) spanning just over 1200 years of the Early and Middle Epipalaeolithic (Richter et al., 2013). Area B dates to the earliest millennium (19830–18850 cal BP) whilst the upper deposits of Area A

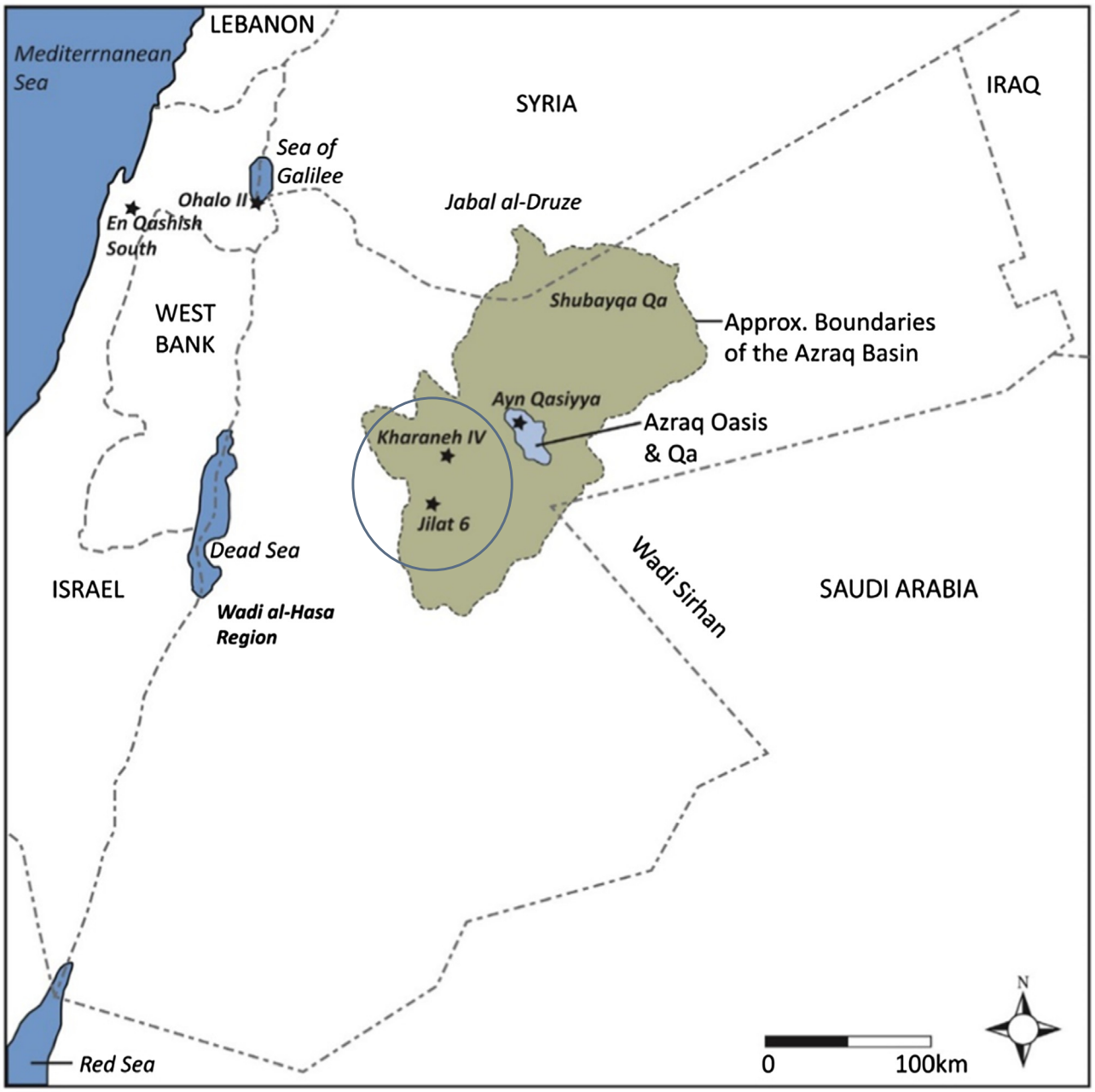

Fig. 1. Map of the Azraq Basin showing the extent of the drainage system in eastern Jordan and the location of Epipalaelithic sites including the eastern Jordanian *megasites* (Kharaneh IV and Jilat 6) (modified from Maher et al., 2016).

(phase 3), which is the focus of the present study, continues later (18800–18600 cal BP). Recent excavations conducted in Area B revealed evidence for at least three hut structures (Maher et al., 2012a) that together with those found at the submerged late Upper Palaeolithic site of Ohalo II on the southwest shore of the Sea of Galilee (Nadel and Werker, 1999; Nadel et al., 2004) represent some of the earliest documented hut structures in the Southern Levant that pre-date the renowned stone houses of the Natufian (Maher et al., 2012b; Ramsey et al., 2018). In addition, Kharaneh IV features a possible subfloor burial, abundant worked bone objects, a ground-stone assemblage as well as caches of symbolic items including gazelle horn-core caches and perforated marine shells from both the Mediterranean and Red Seas (Maher et al., 2012a; Richter et al., 2011, 2013). These material remains suggest prolonged occupation at the site, complex trade networks, a wide range of food processing technologies and symbolic behaviour. The thickness and density of cultural remains led researchers to suggest that the site was visited by large numbers of people staying at the site for long periods of time (Maher et al., 2012a, 2016) and on multi-seasonal or possibly episodic, but year-round bases (Jones, 2012; Henton et al., 2017a). Spatial distribution analysis of animal bone remains conducted in one of the structures (Allentuck et al., 2015) showed that refuse disposal practices relied on principles of taxonomic and anatomical selectivity, which resulted in distinct faunal deposits. This patterning suggests that refuse discard behaviours of seasonally aggregating hunter-gatherers were highly structured, something which can also be attested through the ethnographic literature (O'Connell, 1987; O'Connell et al., 1991). The roots of this behaviour date well back into the Middle Pleistocene, as attested at several Middle Palaeolithic sites in Europe (i.e., Abric Romani; see Vaquero et al., 2001) and the Near East (i.e. Qesem Cave; see Barkai et al., 2017).

Excavations in Area A unearthed several horizontally-extensive occupation surfaces, associated with several superimposed hearths and a

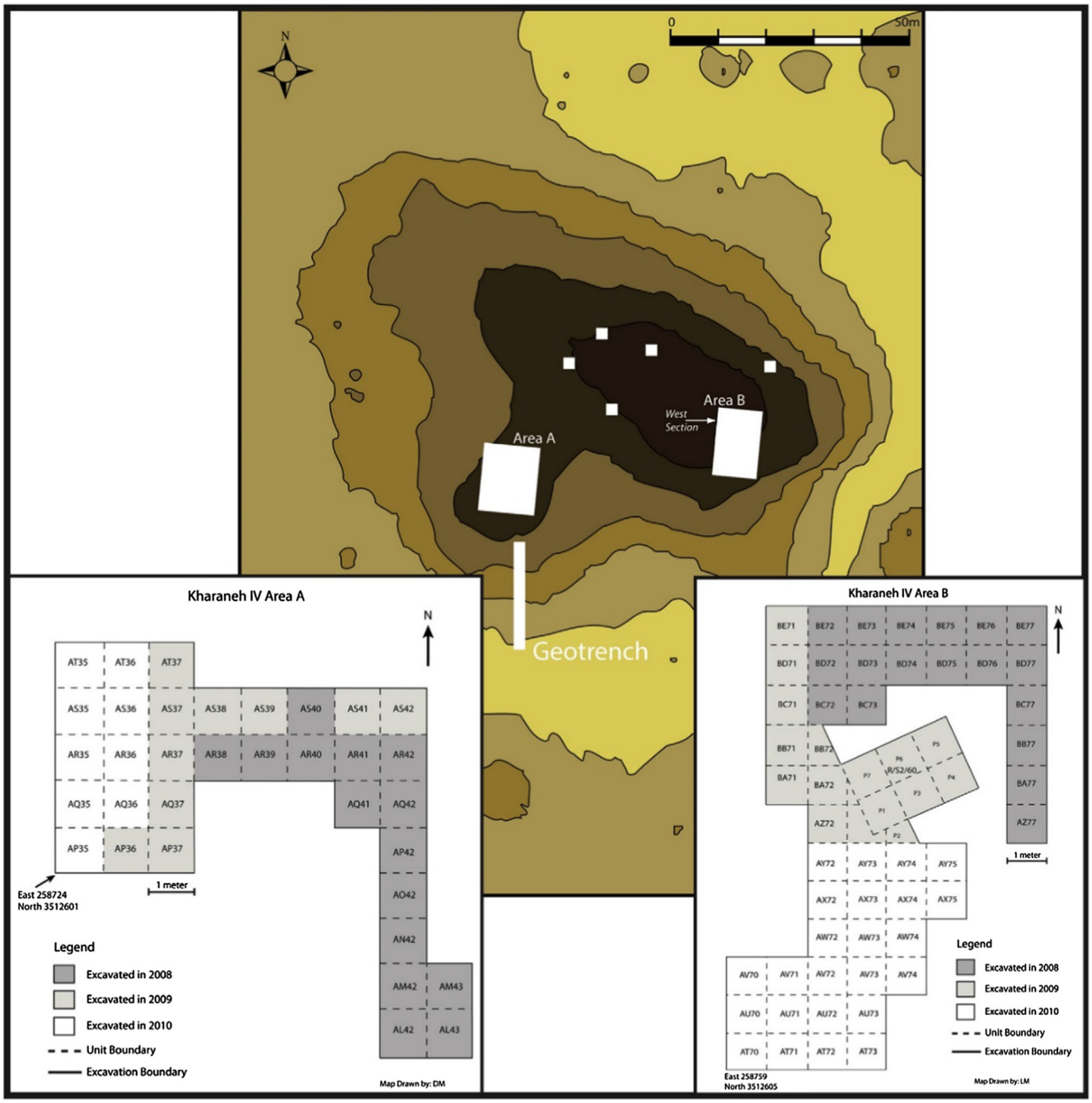

Fig. 2. Topographic map of Kharaneh IV showing the location of main excavation trenches, including Areas A and B (from Maher et al., 2016).

number of small postholes surrounding these hearths, all of which are artifact-rich. These particular deposits were designated by site's excavators as surfaces due to their notable compactness, the presence of *in situ* material (including large animal carcass parts, sometimes articulated), as well as the hearth and postholes dug into them (Fig. 8). The post-holes are all small in diameter, ranging from 5 to 10 cm, and so likely do not represent the supports for any type of substantial structure (Maher et al., 2016: 87). The detailed mapping and absolute dating of the sediments surrounding Kharaneh IV allowed Jones and collaborators (Jones et al., 2016, 2017) to reconstruct to some degree the environmental changes at the site for various time windows over the last 23,000 years. Moreover, on-side evidence demonstrates that during Kharaneh IV 's earliest occupation, it was located adjacent to, and at times inundated by, a local wetland environment, surrounded by semi-arid steppe/parkland (Jones et al., 2016, 2017; Ramsey et al., 2016). Researchers observed that there is little sedimentary evidence from which to reconstruct the environment during the occupation of the site. However they do suggest that the sustained occupation of Kharaneh IV indicates the wetland continues to be a favorable locale for a further 1200 years (Jones et al., 2016: 15; Macdonald et al., 2018).

4. Material and methods

Excavations in Area A were conducted on a 1x1 m grid, however squares were subdivided into 50 × 50 cm quads when finer stratigraphic control was needed. All bone material was derived from one of two retrieval methods; first, 100% of occupation deposits were put through the flotation system, which ensured retrieval of finds at ≥4 mm, ≥2 mm and ≥1 mm sizes. Only fragments larger than 4 mm were used for the current study; second, where animal bones were

Table 2
Body size class breakdown for Kharaneh IV, Area A mammals (modified after Klein and Cruz-Uribe, 1984).

Body-size class	Mass (kg)	Likely species
07	> 1000	Aurochs & Equid
03	15–40	Gazelle
02	< 14	Fox, hare

either very large, fragile or in articulation, they were piece plotted and handpicked to retain integrity. Even though organic preservation at the site is excellent, animal bones are highly fragmented, such that a high proportion of fragments are undiagnostic to genus and species level. However, and since one of the main objectives of this work was to trace carcass processing techniques, all fragments were considered as informative and were analyzed. Undiagnostic fragments were narrowed into general body-size classes, including cranial fragments, vertebrae, ribs and long bone shafts and categorized to a general body-size class in a similar way Klein and Cruz-Uribe (1984) proposed for African mammals (Table 2). Fragments which could not be identified into size class or body-zone were counted and weighted under the category of *miscellaneous*. All diagnostic material was analyzed using a coded tailor-made database structure (Access, 2010). The identification and recording of bone classed as diagnostic was carried out using collections at the UCL Institute of Archaeology London, while bird species identification was undertaken using collections at the Natural History Museum at Tring, Hertfordshire UK.

A total of 10839 mammal and bird bone fragments were identified, recorded and analyzed from Area A during the 2010 field season, from which only 3670 (representing 34% of the total sample) could be securely identified to taxon/species and body part, while the remaining 7169 fragments (66% of the sample) were only assigned to a general body-size category based on the size and thickness of bone shafts.

The remainder of the bone assemblage comprised c.33000 *miscellaneous* fragments. In general, post-depositional disturbance at the site was minimal. All identified bone fragments were systematically checked for bone surface modifications. Few specimens (3%) display a weathering stage higher than 2 (of Behrenshmeyer's, 1978 six stages), indicating rapid burial of the faunal material and lack of postdepositional trampling. Noteworthy is the absence of carnivore activity, something which is in agreement with other Epipalaeolithic assemblages (Martin, 1994; Martin et al., 2010; Rabinovich, 1998, 2002b; Rabinovich and Hovers, 2004). The absence of carnivore activity within the studied assemblage may be related to either the intensive carcass processing methods (Lupo, 2001) used at the site or to occupation intensity whereby the presence of humans may have inadvertently protected their trash from scavengers (Bunn, 1993). Proportions of burnt bone were found to be significantly low (7%) despite the fact that hearths and fire patches are common at the site. Burning in the studied sample occurs at higher frequencies on the unidentified fragments (Table 6). However, proportions of burnt bone fragments vary across contexts, such that the spatial distribution of burnt bone might provide a better picture of cooking/processing and post-discard activities. The majority of burnt bone fragments belong to gazelle feet (carpals, tarsals and phalanges) while few gazelle-size longbone shafts were burnt. Additionally long-bone epiphyses, which might be indicative of roasting activities appeared unburnt. This anatomical distribution of burning does not seem to be correlated with fat/meat utility parts but perhaps with post discard exposure to the flames. The low level of burning does not imply that meat was not roasted or boiled or cooked, as it is still debatable whether most cooking practices leave any visible traces (Roberts et al., 2002). It has been proposed, however, that roasting is likely to be identifiable through charred ends of longbones (Crader, 1984; Speth, 2000) and this has not been the case of the Kharaneh IV long-bones, where epiphyses appeared unburnt. Moreover, most gazelle-sized shaft fragments display equal burning intensity externally and internally indicating that most of the burning resulted from nonnutritive incidence that occurred following defleshing and breakage of bones (Yeshurun et al., 2007: 667).

Table 3
Taxonomic abundance shown as NISP, NISP% and MNI, Kharaneh IV, Area A. ID = Total number of identified specimens.

Taxon (latin name)	Taxon (common name)	NISP	%NISP	MNI
Equus caballus/E. hemionus	Horse/wild ass	156	4.25	3
Bos primigenius	Wild cattle	24	0.65	1
Gazella cf.*subgutturosa*	Goitered gazelle	3291	89.67	36
Hyaena sp.	Hyaena	1	0.03	1
Canidae	Wolf/jackal/dog	6	0.16	1
Vulpes vulpes	Fox	32	0.87	1
Lepus capensis	Hare	140	3.81	4
Erinaceus sp.	Hedgehog	5	0.14	1
Testudo graeca	Tortoise	9	0.24	1
Buteo buteo	Buzzard	1	0.03	1
Fulica atra	Coot	1	0.03	1
Falco tunninculus	Kestrel	3	0.08	1
Struthio camelus	Ostrich	1	0.03	1
Total ID 3670				

5. Results

5.1. Animal procurement strategies

Table 3 provides the Number of Identified Specimens (NISP) and the Minimum Number of Individuals (MNI) for different taxonomic groups, giving both Latin species names and common names. Gazelle bones comprise 89.7% of the total sample, while large ungulates such as equidae (4%) and aurochs *Bos primigenious* (< 1%) represent only minor components of the Middle Epipalaeolithic assemblage. About 4% of the identified sample was assigned to small animals including hare (< 4%), fox (< 1%), and medium-size carnivores (i.e., hyena and jackal, < 1%). Tortoise accounts for 0.2% of NISP and consists mainly of carapace and plastron fragments and only a few long bones. Bird remains contribute the remaining 0.1% of the assemblage and those have been identified to ostrich (*Struthio camelus)*, buzzard (*Buteo buteo)*, coot (*Fulica atra*) and common kestrel (*Falco tinnunculus*).

The discussion below focuses exclusively on gazelle since it is the dominant taxon found at the site while detailed information on other taxa including sub-species differentiation, mortality profiles and carcass treatment can be found elsewhere (Spyrou, 2015). Morphometric analysis conducted on gazelle postcranial elements showed that these fall in the large size-range of the goitered gazelle *Gazella subgutturosa* and those results are in agreement with previous zooarchaeological studies conducted at the site as well as other equivalent period sites located in eastern Jordan (Martin, 1994; Martin et al., 2010, Yeomans et al., 2017). Sub-species identification was confirmed by detailed examination of several well-preserved male horn-cores which showed the lyrate twisting and divergent morphology, typical of *Gazella subgutturosa* (Compagnoni, 1978: 119; Harrison and Bates, 1991; Uerpmann, 1982: 27; Fig. 3).

In order to better understand the pre-eminent role of gazelle within the assembled prey, the faunal composition of the studied assemblage was compared to published data from other sites of similar date, located in different and similar ecological settings. Taxa, or taxonomic groups, have been divided by colour into six broad categories according to their size, speed and favoured environments (Fig. 4). Even though gazelle dominate most Epipalaeolithic assemblages, frequencies vary between the different occupations, ranging from 38% at Wadi Jilat 22 (Martin et al., 2013) to 89.7% at the Middle Epipalaeolithic levels of Kharaneh IV. Gazelle proportions never exceed 72% in assemblages from sites located to the west of the Sea of Galilee where instead cervids

Fig. 3. Male adult gazelle horn-core showing the lyrate form and the twist, typical of *Gazella subgutturosa* (lower image); young male horn-core (upper image). Kharaneh IV, Area A.

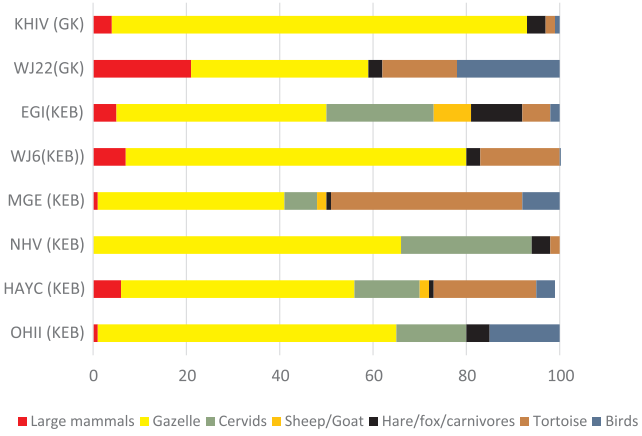

Fig. 4. Relative abundance (%) of prey at Kebaran (KEB) and Geometric Kebaran (GK) sites in the Levant. **OHII = Ohalo II** (Rabinovich and Nadel, 2005; Simmons and Nadel, 1998); **HAYC = Hayonimc Cave C** (Stiner, 2005); **NHV = Nahal Hadera V** (Bar-Oz 2004; Bar-Oz and Dayan 2002); **MEG = Meged Rockshelter** (Stiner 2005); **WJ6 = Wadi Jilat 6** (Garrard and Byrd, 1992); **EGI = Ein Gev I** (Marom and Bar-Oz, 2008); **WJ22 = Wadi Jilat 22** (Martin et al., 2013); **KHIV = Kharaneh IV** (**present study**).

contribute significantly, accounting for 7–28% NISP. It is also notable that a wider range of species occur at sites located to the west and north of the River Jordan and closer to permanent water sources, with the most characteristic example being the sub-merged Upper Palaeolithic site of Ohalo II, (Rabinovich and Nadel, 2005) while species diversity declines further to the east. Surprisingly and despite its proximity to Kharaneh IV, Wadi Jilat 22 has very low gazelle proportions accounting for only 38% (Martin et al., 2013). Wadi Jilat 22 has been ascribed as an "atypical" eastern Jordanian site in that it includes notably high numbers of birds (23.6% NISP for the Middle Epipalaeolithic levels) and tortoises (16.8%; Martin et al., 2013). Bird bone identification indicated that most were birds of prey (i.e, eagles, raptor, vultures) and more likely served decorative/symbolic purposes rather than culinary ones (Martin et al., 2013: 656).

The dominance of gazelle over other animals at Kharaneh IV should be interpreted within an ecological context. Despite lacking the rich vegetational mosaic of the western Levant, eastern Jordan's wetland systems might have played an equivalent crucial role for Late Pleistocene hunter-gatherers' adaptations (Byrd, 1994; Ramsey et al., 2016; Olszewski and Coinman, 1998) providing important grounds for innovation. The abundance of localised wetland resources including sedges and reeds (Ramsey et al., 2016) in combination with the high numbers of gazelle may have led Epipalaeolithic foragers occupying this area to follow very different paths from their counterparts, to aggregate in large groups and settle for longer in one place (Ramsey et al., 2016: 26).

5.2. Hunting practices

The timing of game acquisition is of significance to hunters around the world (Driver, 1990, Speth, 1987). Animal characteristics, including nutritional condition, palatability of meat and other nutrients, quality of the fur, and composition and behaviour of herds all, vary within different seasons. Since hunting and subsequent carcass processing seem to be dominant activities at Kharaneh IV, there's a need to consider hunting strategies and the timings of animal capture, questions also of relevance to the nature of hunter-gatherer occupation of the steppe/desert areas in prehistory (Maher et al., 2012a, Garrard and Byrd, 2013), and also to debates about gazelle intercept mass-capture techniques (e.g. Betts, 1993).

Seasonality of hunting is explored through the reconstruction of gazelle mortality profiles combined with previous research results from the site, including gazelle dental cementum analysis (Jones, 2012) and isotopic analyses (Henton et al., 2017, 2018), the identification of migratory birds, and alongside gazelle behavioural ecological studies (Martin, 2000). Cull pattern and seasonality data from the current study is limited due to the high fragmentation of gazelle mandibles, making it impossible to use tooth eruption/wear; instead postcranial epiphyseal fusion has been employed to estimate the proportions of juvenile gazelles culled, even though this method does not provide finescale ageing resolution. There is no published data of longbone epiphyseal fusion timing in the goitred gazelle (*Gazella subgutturosa*) but we used fusion data for the mountain gazelle (*Gazella gazella*) as a reasonable proxy (Davis, 1980; Munro et al., 2009) since the two taxa are similar sizes and occupy overlapping habitats, and little variation is seen in fusion sequences. A summary of gazelle epiphysial fusion data is presented in Table 4 where four main age groupings of elements provide key information (Davis, 1980; Munro et al., 2009). The fusion data demonstrate that less than 10% of animals were killed prior to 10 months of age. By 8–10 months mortality was c. 21.5%, which increased to 35.5% by 10–18 months, meaning that approximately 36%

Table 4
Gazelle fusion data (Kharaneh IV, Area A) with numbers adjusted to reflect standard numerical weighting of elements (following Davis, 1980; Munro et al., 2009). Pc = postcranial.

Gazelle fusion data

Element	Unfused	Fused	%Fused
Distal humerus	2	54	
Proximal radius	5	167	
c. 2 months	7	221	97.4
Proximal 1st phalanx	6	300	
Coracoid scapula	2	44	
3–8 months	8	344	97.7
Distal tibia	29	83	
8–10 months	29	10	79.5
Proximal humerus	16	11	
Distal femur	20	14	
Proximal femur	43	60	
Calcaneum	70	180	
Distal metapodials	12	8	
Proximal tibia	14	47	
Distal radius	10	17	
Proximal ulna	0	0	
10–18 months	191	347	64.5
Total with fusion information 1230			

35.5% juvenilles (based on 10–18 month fusion group) taken as juveniles

Newborn pc ends 6

Total n pc ends 2950 0.2%

of the gazelle herds targetted died as juveniles. This figure would reflect normal gazelle population demography in herds that give birth only once a year (Baharav, 1974; Martin, 2000) and results are in agreement with previous zooarchaeological studies from Kharaneh IV (Martin et al., 2010), generally indicating herds which are not over-hunted or experiencing hunting pressure. The presence of a small number of newborns within the studied assemblages (0.2%) might indicate either selective targetting of older animals or an avoidance of newborns, although this is impossible to interpret further. Gazelles in the Epipalaeolithic of eastern Jordan are assumed to have synchronized their births in spring when nutritious grasses flourished, ensuring maximal survival of both mothers and their young (Martin, 2000), an assumption supported by recent isotopic studies (Henton, 2017, 2018).

Three previous studies provide evidence for reconstructing gazelle hunting seasonality at Kharaneh IV. First, earlier zooarchaeological work used gazelle epiphyseal fusion evidence to infer primarily winter culling with some evidence for spring culls too (Martin et al., 2010). Second, pilot studies on gazelle dental cementum samples from the site (Jones, 2012) found evidence for both spring/summer and autumn/winter culls. Third, oxygen and isotope studies on the dental enamel of gazelle samples from the site indicated primarily winter culls, with spring and early summer also represented (Henton et al., 2017). Evidence clearly gives an inconsistent picture, but most studies agree that winter was a prime hunting season, with some animals taken in other seasons too. Most of the birds identified in the current sample including the highly adaptable ostrich *Struthio camelus* and the common kestrel *Falco tinnunculus,* are likely to have been permanent residents (Andrews, 1995). However the presence of the Egyptian vulture *Neophron percnopterus* indicates summer visits. It must be borne in mind, however, that the site may have been used as a hunting base for different animals/birds in different seasons.

For the present study, methods of animal capture are explored through a closer examination of herd composition and age/sex selection. As shown above from the fusion data, gazelle profiles do not indicate targetting or selection of particular age groups. In order to explore possibilities of sex selection we apply morphometric analysis using the scapula glenoid, an anatomical region displaying high sexual dimorphism (Horwitz et al., 1990; Munro et al., 2011).

Measurements taken on the glenoid's Greatest Breadth (BG) are plotted against the Greatest Length (GLP) (Horwitz et al., 1990; von den Driesch, 1976). Results are shown in a bivariate plot (Fig. 5) and see specimens falling into two size categories, indicating an almost equal representation of larger adult males and smaller adult female animals. While inconclusive in itself, this evidence for equal representation of females and males, alongside the fusion data showing a roughly 'live herd' demography, might be consistent with the idea of hunting large mixed winter gazelle herds. In a previous study Martin and collaborators (2010) observed a significant increase in the proportion of juvenile animals between the Early (25–27%) and the Middle Epipalaeolithic phases of Kharaneh IV (34–35%; Martin et al., 2010: 120). Since taphonomic factors had been excluded as differentially affecting the preservation of juvenile bones between the two phases, the authors suggested that larger-herd hunting might have replaced smaller-scale-individual stalking during the Middle Epipalaeolithic and that it was possible that large-scale capture of gazelle may have represented a seasonal affair at Kharaneh IV.

Based on recent isotopic analysis of gazelle teeth, Henton and colleagues (Henton et al., 2017, 2018) suggest that gazelle herds were present and sustained year-round in the eastern Jordan limestone steppe during the Epipalaeolithic, without recourse to long-distance seasonal migrations. The model favoured by Henton and colleagues is that of a localised seasonal aggregation and dispersal of gazelle herds, following vegetation availability and herd reproductive cycles (Henton et al., 2017: 156). It seems that Wadi Kharaneh may well have been an attractive winter location for hunting large mixed gazelle herds, clustered around denser winter forage resources.

This picture raises questions about the methods of hunting, and whether traps may have been used. Current research finds the earliest firmly dated hunting 'kite' structures to be from the late PPNB in southern Jordan (Abu-Azizeh and Tarawneh, 2015), although this clearly doesn't preclude earlier traps and walls being used. Aslo, kite structures and other stone walls associated with animal entrapment in the Jordanian and Syrian deserts are mainly (but not exclusively) found in the areas of basalt desert (Helms and Betts, 1987; Zeder et al., 2013); we might not expect to see them in limestone areas such as that surrounding Kharaneh IV. That said, mass-trapping of animals could have been easily achieved without the use of structures that would survive archaeologically (i.e., organic hunting blinds, bush); such strategies might include firing of grasslands during the dry seasons and such planning has been recorded amongst ethnographically known hunter-gatherers such as the Akwe-Shavente (Maybury-Lewis, 1974), the Apinaye (Nimuendajú, 1939) and the Gbaya (Burnham, 1980: 154–155). Other possible encounter strategies could include the surrounding technique in which a large number of hunter-gatherers encircle a group of unsuspected animals (Speth, 1997). The zooarchaeological evidence discussed above does not allow interpretation of mass-hunting or trapping techniques, but these methods cannot be discounted either, and indeed may not be surprising given the high proportion of gazelles taken, as we propose, in winter seasons when they are predicted to been found aggregated in high densities around water sources such as those witnessed at Kharaneh IV.

5.3. Gazelle carcass utilization

Although not evenly distributed, all gazelle major skeletal elements are present within the studied assemblage suggesting that complete animal carcasses were transported from the kill site to the camp. This is not surprising, given the light weight of a medium-sized class antelope

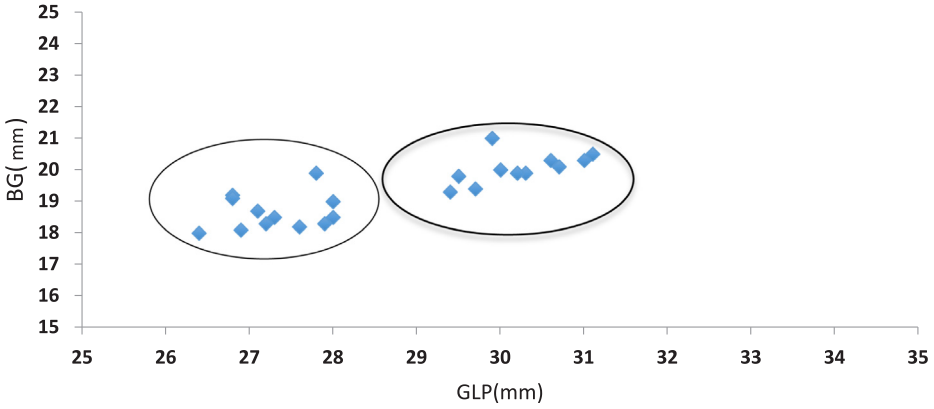

Fig. 5. Bivariate plot showing gazelle scapula glenoid greatest breadth (BG) versus greatest length of the glenoid process (GLP) and highlighting the degree of sexual dimorphism (Kharaneh IV, Area A). The first cluster probably represents adult female animals while the second cluster adult male animals. NB sexual dimorphism ratio (M/F(M-F/M = %D) estimated for gazelle; BG%D = 10.9; GLP %D = 7.5 (dimorphism index follows Horwitz et al., 1990; metrics follow von den Driesch (1976).

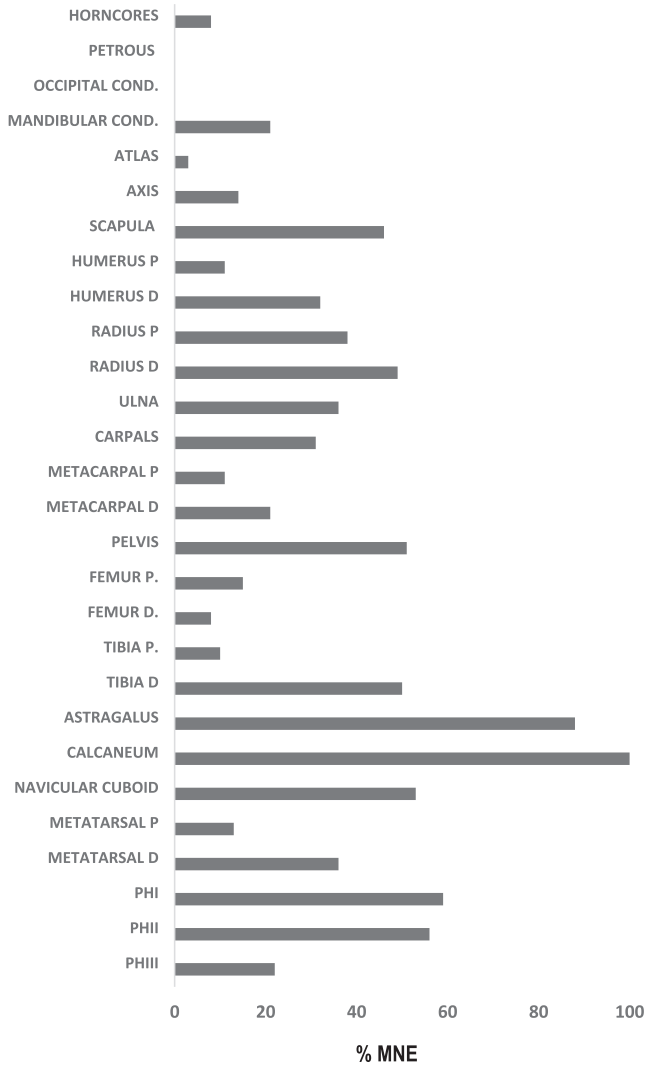

Fig. 6. Minimum Number of Elements (MNE) % survival of gazelle body-parts (dentition has been excluded since gazelle mandibles and teeth were highly fragmented at Khareneh IV).

(20–28 kg for *Gazella subgutturosa* f/m Garrard, 1980). Skeletal element abundance for gazelle was estimated by using the Minimum Number of Elements (MNE), a useful measure for assessing body part usage, particularly in hunter-gatherer assemblages and especially where material has experienced high fragmentation as with Khareneh IV.

Gazelle elements well above the 50% representation level include pelvis, astragalus, calcaneum, navicular cuboid, and first and second phalanges whilst elements with very low percentage representation include mandibular condyles, atlas and axis, proximal and distal femur, proximal humerus and proximal tibia as well as proximal and distal metapodia (Fig. 6). The absence of diagnostic skull fragments, including the very dense petrous bone (*os temporalis)* and occipital condyles, is challenging to understand and should not be taken as an artifact of preservation since petrous has high structural density (1.29GR/cm^3 based on BMD_{1+2} values for *Rangifer tarandus*; Bar-Oz and Dayan, 2007: 1356; Lam et al., 1999: their Table 1). The apparent transportation of skulls to the site is attested, primarily through the presence of horn-cores but also by the high numbers of unidentified skull fragments belonging to medium-sized animals (almost certainly gazelles) found in Locus 035 (see below). Ethnographic accounts of brain processing may provide some clues for the lack of diagnostic skull fragments at the site. Animal brain has been acknowledged as an extremely nutritious foodstuff and contains important deposits of lipids that persist even in the most severely stressed animals (Speth, 1991; Stiner, 1994: 228–229, 267). Brains are edible and palatable and they are rich in lipids, particularly the long-chain polyunsaturated fatty acids (LCPUFA'S), docosahexaenoic and arachidonic acid. Hobbs (1989) informs us that the Ma'aza Bedouins who live in Egypt's Eastern desert prepare a portable snack in which the main ingredient is brain and fat extracted from the ibex's head. "Fat from the head is often retained as a snack and called *ash-shaham*: boiled with salt, suet is packed into the ibex's stomach, which is rolled in flour and kept shaded. This food is kept cold and is edible for up to four months" (Hobbs, 1989: 52). However, ethnographic literature demonstrates that hunter-gatherers across the world are more prone to use animal brains for tanning animal hides rather than as a supplementary source of nutrition since the cancellous material contained within the animal brain could have an abrasive function (i.e., Belitz, 1973). Moreover and as Speth highlights LCPUFA's are very unstable and readily oxidized and if not handled properly (deliberately rotted or fermented) they may produce hyperoxides and other byproducts that are potentially toxic for humans (Speth, 2018: 226). Therefore, the lack of petrous bone from the current sample might indeed suggest some form of intentionall smashing of gazelle heads for brain extraction and consumption/use in tanning animal hides and disposal of petrous bone in an area outside the limits of the camp.

The low representation of diagnostic long-bones, including femora, humeri, radiae and metapodia cannot be explained by density-mediated attrition (Lyman, 1994), as these elements have particularly high structural densities. Notably, however, the most common undiagnostic bone size fraction is actually the gazelle-sized (03) long-bone splinters. In order to evaluate the human or post-depositional agents responsible for the extreme fragmentation of gazelle major limb bones, a sub-study of gazelle-sized long bone fragments was undertaken. The morphology of the fracture angle, fracture outline, and fracture edge was recorded for all shaft fragments that were connected to a portion of a gazelle long bone epiphysis as well as for all midshaft fragments following Villa and Mahieu's (1991) protocol for human remains that allows distinction of fresh from post-burial breaks.

Analysis of breakage patterns revealed a predominance of fragments with oblique angles, V-shaped outlines and smoothed edges, all indicative of prehistoric-aged bone breakage (Spyrou, 2014; Villa and Mahieu, 1991; Fig. 7). Moreover, the relationship between

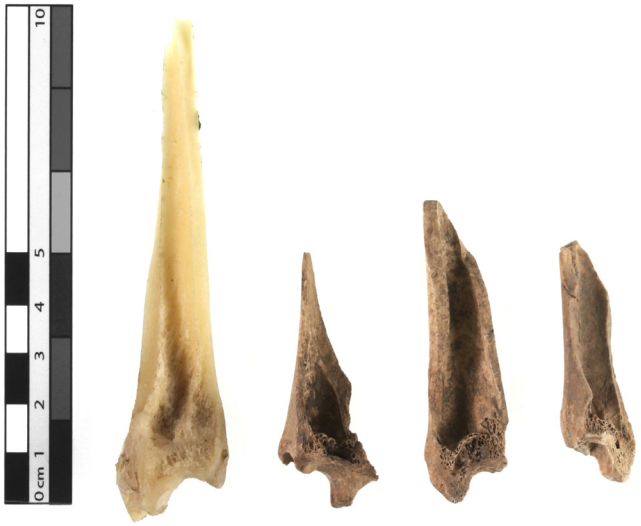

Fig. 7. Examples of fragmented distal tibiae with evidence for fresh (green) fractures (NB; Oblique angles, V-shaped outlines and smoothed edges, all indicative of prehistoric, pre-depositional break. Specimen on the left is modern and has been produced during a marrow extraction experiment with roe deer long bones. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

fragmentation index (NISP: MNE) and marrow content of the major gazelle long bones (based on experimental data provided by Bar-Oz and Munro, 2007), shows that elements with the highest marrow content, including femur and tibia were those most heavily fragmented, suggesting intentional smashing of gazelle major limb bones for the extraction of bone marrow. It is also noteworthy that size distribution of gazelle-sized shafts shows similarity in sizes with most of the fragments falling in the medium-sized (03) category and ranging between 3 and 5 cm (Fig. 7). Enloe (1993) argues that mass processing of animal carcasses, with the aim of marrow storage, is a standardized breakage procedure resulting in less variability (and consistency) in fragment lengths; whereas considerable variability in fragment sizes is associated with fortuitous or incidental breakage during meal consumption or snacking (Binford, 1978; Enloe, 1993: 89). The similarity in shapes and sizes found within the gazelle long-bone assemblage suggests that breakage at Kharaneh IV was consistent. Given the limited overall amount of fat in the carcass of gazelle (Ostrowski et al., 2006) one begins to realize the high importance of the lipids in the marrow cavities of the limb bones and the grease that could be boiled or stewed, from the cancellous tissue of limb epiphyses, vertebrae and flat bones such as ribs and sternebrae.

The low representation of metapodia, especially proximal metacarpal and metatarsal, is surprising since they are expected to survive well, and likely related to their removal during an early stage of carcass processing for use in the bone tool industry for which there is strong evidence at the site (Martin, 1994; Martin et al., 2010; Maher et al., 2012a).

From the total 3291 (NISP) diagnostic gazelle bone fragments, only 75 (2.3%) displayed direct evidence of butchery in the form of cut or chop marks. The majority of butchery marks associated with the gazelle-sized class are attributed to dismemberment (n = 61), following Binford's descriptions, and these have been found on every single type of articulation, including both proximal and distal gazelle long-bone epiphyses (Fig. 8). The number of cut marks made during decapitation is relatively low (0.6%), and likely related, in part, to the scarcity of atlas/axis and occipital condyles. Looking at the diagnostic gazelle fragments, filleting marks are relatively uncommon, but are most commonly found on ribs, scapulae, metapodia and calcanea. However, if we take into account the gazelle-sized shaft splinters (n = 22) and ribs (n = 19) removal of thin strips of meat seems to have been a relatively common activity at the site. The relatively high frequency of filleting marks on gazelle bone is interesting and may relate to meat stripping, meat drying, smoking or salting and storage of strips of meat for later consumption (Enloe, 2003).

5.4. Spatial distribution of gazelle body-parts

In order to better understand how carcass processing activities were structured within the site, the last part of our study involved examining the spatial distribution of gazelle body-parts. Only squares excavated during 2010 have been considered and those cover an open area of 9 m^2 (Fig. 9). Material selected for this study derives from two securely defined contexts which have been stratigraphically undisturbed and preserve evidence for some *in situ* features, including a series of post-holes. Locus 034 is found in the northern-most squares of Area A (**AT35, AT36, AS35, AS36, AR35, AR36**), and it represents a compact surface very rich in charcoal and organic matter. Due to the compact nature of its sediment, it was interpreted as a living surface (Maher et al., 2009, 2010). Moving south, Locus 035 (**AQ35, AQ36, AP35**) is characterized by very loose sediment with frequent charcoal inclusions that increase with depth. This locus is adjacent to and, stratigraphically contemporary with Locus 034. In Squares AQ36 and AP35, Locus 035 is cut by a number of small size, shallow depressions (5–10 cm diameter), which are in close proximity to each other (Fig. 10).

These are primarily circular in plan, ranging from a depth of 3–10 cm and are infilled with high densities of bone and lithic material. They are interpreted as post-holes. The post-holes do not appear to be related with any substantial structures, such as the hut structures found in Area B (Maher et al., 2012b). Adjacent to the concentration of postholes a ca. 40 cm patch of ashy, dark brown loose sediment was identified and as the feature was sectioned, several overlapping hearth deposits were identified, representing at least two successive periods of hearth construction and use in the same location (Maher and Macdonald, 2013; Maher et al., 2008, 2009, 2010). Significant differences in bone densities, levels of bone identification, burning intensity and distribution of gazelle body-parts within the two contexts have been highlighted. Locus 034 appears relatively "clean" in terms of bone waste compared to the southern-most Locus 035. It is characterised by lower bone densities (Table 5), higher levels of bone identification and very low proportion of burnt bone compared to Locus 035 (Table 6). Among the most interesting finds from this context is a refitted tortoise carapace found together with pieces of red ochre and two complete

Fig. 8. Encountered cut marks observed on gazelle limb bones: dismemberment marks on first and third specimens; filleting marks on specimen in the middle.

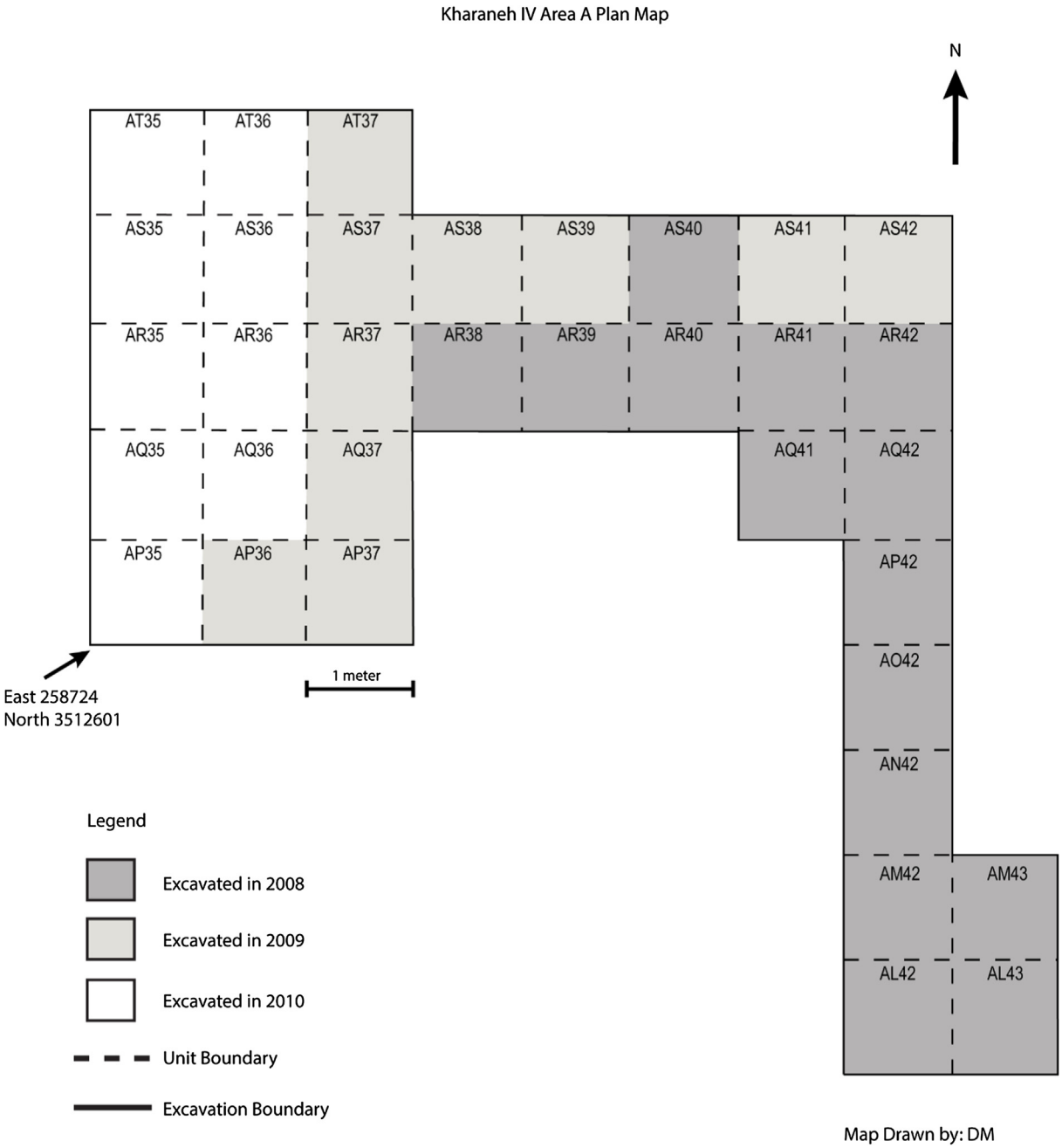

Fig. 9. Plan showing the site's grid in Area A. White areas indicate squares excavated in 2010 and which produced faunal material for the present study (drawn by Danielle Macdonald).

gazelle metapodia that might imply storage of items invested with some value (Spyrou, 2015). On the other hand, Locus 035 is characterised by higher bone densities, lower levels of identification and a higher proportion of unidentified and burnt bone (Table 6)

In order to search for anatomical patterning within the two contexts, gazelle body parts have been assigned into six broad categories including; (i) skull fragments; (ii) vertebrae; (iii) ribs; (iv) innominatae; (v) meat-rich long bones; (vi) unidentified shaft fragments. Surprisingly, and while vertebrae and ribs in Locus 034 are very low in numbers, these elements dominate Locus 035, and particularly in squares AQ36 and AP35 with sternum, atlas, axis and other vertebrae found in a relatively good state of preservation and some even being semiarticulated, suggesting *in situ* processing of the back-bone for meat and immediate deposition here without further processing.

Ethnographic studies of butchery and meat preservation through drying (Binford,1978; Friesen, 2001) suggest that elements such as vertebrae, ribs, scapulae and pelvises represent bone-meat packages which are ideal for preservation through drying as meat is distributed in a relatively thin layer on the bone (Table 1). The spatial clustering of these elements close to the series of post-holes and hearth construction might indicate that meat drying/smoking was practiced in this area and the post-holes might represent the remains of one or several drying racks. Binford (1978) noted that in many cases, Nunamiut foragers put the entire vertebral column with ribs attached on their drying racks prior to removal of strips of meat. "Meat is placed on the drying racks in a fairly standard fashion, rib and sections of the vertebrae are almost always suspended from the vertical tripod poles or from the ends of horizontal poles. During the butchering of rib slaps a slit made by the butcher between the fourth and fifth rib served as a handhold during the removal of the rib slap. This silt is used for suspending the rib slaps

Fig. 10. Kharaneh IV, Area A postholes (Square AP35, Locus 035; Photo taken from EFAP Archive).

Table 5
Number of bone fragments (N) and volumetric (Vol.) densities for each square from which animal bones have been collected for contextual analysis, Kharaneh IV, Area A (Locus volumes and number of bone fragments were combined to estimate Vol. densities: NS/Litre).

Square	Locus	Litres	N	Vol. densities
AT35	034	55	277	5
AT36	034	92	445	5
AS35	034	68	303	4
AS36	034	80	736	9
AR35	034	65	708	11
AR36	034	75	294	4
AQ35	035	87	655	8
AQ36	035	63	1079	17
AP35	035	97	1259	13

from the drying rack. Vertebrae are generally butchered into a single unit beginning with the first thoracic vertebrae and ending with pelvises" (Binford, 1978: 97).

The idea that articulated vertebrae and rib cages were suspended on the drying rack is further supported by the virtual absence of cut marks on vertebrae corpi and rib heads suggesting that those have possibly been treated as single units. It is also worth noting that a high number of patellae were recovered from Locus 035. Patellae are rarely discussed in zooarchaeological reports (although see Friesen, 2001; Frison, 1991); however, in these contexts they may provide crucial evidence on the treatment of gazelle hindlimbs as according to Frison (1991: 312) in muscle stripping of the hind leg, the patella was used as a hand-hold. Thirty specimens were recorded from Square AQ36 representing at least 15 individuals and it is possible that kneecaps had remained attached to the meat stripped from the associated femora and tibiae.

Proportions of burnt bone fragments within the studied squares range from 3 to 25%, with the highest proportion of burnt bone found in locus 035, particularly in squares AQ35 and AP35 (Table 6). As it has been highlighted above, the majority of burnt bone belongs to unidentified fragments and to gazelle foot bones, including phalanges, carpals and tarsals. This bone burning pattern is perhaps consistent with the the presence of a hearth located on top of earlier refuse and thereby unintentionally inflicting secondary burning on bones burried underneath.

6. Discussion

We have provided above combined contextual and zooarchaeological evidence that leads us to propose that the series of postholes found in Area A (Locus 035) may represent a small ephemeral structure such as a meat drying rack; similar structures might also exist in other areas of Kharaneh IV as well as at other sites in the wider region. Our aim here is neither to assume that meat preservation appeared for the first time at Kharaneh IV, nor that storage was a technological innovation of the Middle Epipalaeolithic; this behaviour must have its roots much deeper in time and was probably a common ecological knowledge widely spread during the Middle Epipalaeolithic. What makes Kharaneh IV so far unique, however, is the empirical evidence that contributes to the archaeological visibility of a practice that has been assumed or under-explored to date in discussions of the Levantine Epipalaeolithic.

The technology undepinning food storage is currently thought to have originated in Europe during the strongly seasonal climates of the Upper Palaeolithic (Hoffecker, 2005; Lumley et al., 2004; Pryor, 2008), although meat preservation through freezing and fermentation could well have been common practice among Neanderthal (Sørensen, 2009) and pre-Neanderthal groups (Speth, 2017). Meat preservation through freezing was easy to achieve in the periodic subzero temperatures of Eastern and Northern Europe as animal carcasses needed only to be butchered into sections and then placed in caches or pits that served as natural refrigerators (Friesen, 2001: 315). In a recent article, Speth (2017) considers the vital role that deliberately fermented/rotted meat and fish might have played in the survival and adaptive success of Eurasian Neanderthals and their Upper Palaeolithic successors. Fermented and rotted animal foods could have been placed in shallow pits, or under piles of rocks, allowing Palaeolithic foragers to create valuable food caches at strategic points on the landscape. He further suggests that such dispersed forms of food caching might have played a key role in prehistoric hunter-gatherer decisions, including when and where to

Table 6
Distribution of 1) Identified (ID) and Unidentified (UN) gazelle burnt bone fragments and distribution of gazelle skeletal elements including skull, vertebrae (Vert), Ribs, Pelvis and Identified (ID) long bones within the different squares, Kharaneh IV, Area A. Bold areas show the concentration of skeletal elements with high Drying Utility Index (Following Friesen, 2001; Table 1).

Square	Locus	Burning %		Distribution of gazelle skeletal elements						
		ID	UN	Skull	Vert.	Ribs	Pelvis	ID. Long bones	Shaft fragments	N
AT35	034	0	3	0	0	41	5	12	176	234
AT36	034	0	5	12	6	49	4	8	154	233
AS35	034	1	8	0	0	12	3	14	109	138
AS36	034	0	7	12	2	65	3	5	130	216
AR35	034	1	6	21	4	60	3	7	120	215
AR36	034	2	8	10	5	45	2	31	110	163
AQ35	035	4	12	21	23	95	17	19	82	257
AQ36	035	7	17	24	**220**	**120**	**28**	74	278	744
AP35	035	1	24	46	**125**	**164**	**44**	107	302	788

move and the route they should take in order to get to their final destination while minimizing the specter of starvation en route (Speth, 2017: 62).

In contrast to freezing and fermentation which are low-cost and low-technology food preservation methods, meat drying is a more complex process that requires specific constraints in butchery (Binford, 1978), time and labour investment for the construction and maintenance of relevant facilities including drying racks (Sharp and Sharp, 2015), technological awareness for the control of wind and fire, fuel and specific ecological conditions. Meat-drying, while ethnohistorically and ethnographically one of the most frequently documented methods used by hunter-gatherers to preserve meat (Sharp and Sharp, 2015: 43–55; Stopp, 2002: 309–312), involves procedures (e.g., cutting the meat into thin strips) and facilities (e.g., wooden drying racks) that are ephemeral and difficult to detect in the archaeological record. Archaeological examples dating back to the Late Pleistocene, are exceeding rare, making the case presented in this paper of considerable significance. Even though elaborate food processing technologies have been reported and described from other Late Pleistocene hunter-gatherer sites, such as above-ground ovens (Piperno et al., 2004), grinding stones (Wright, 2004) and fermentation technologies (Boethius, 2016), preservation of meat and other animal nutrients has not yet been demonstrated from other Late Pleistocene sites in the Southern Levant.

So how and where did Kharaneh IV foragers preserve gazelle meat? Gazelle dried meat might have been shredded and pounded to produce a paste for further mixing with fat or ground to produce a meat powder which could be used for the preparation of stews. Similar to drying, smoking could also be easily achieved with the use of smoky wood fires (Geist, 1978) and such a procedure would facilitate the drying process while also adding extra flavour to the meats (Atalay and Hastorf, 2006). In addition to sun/wind drying and smoking, another possible preservation technique that needs to be considered is salting. Although no direct evidence was found at the site in the form of preserved salt deposits such as those found at the Neolithic site of Catalhoyuk (Atalay and Hastorf, 2006: 298; Mathews, 2005), pits which might have been used for such purposes are abundant at Kharaneh IV. Access to salt would have been possible during the seasonal drying of nearby playa lakes, or in the nearby Azraq wetlands, or even longer-distance trade with groups near the Dead Sea. According to Hemsley and George (1966) and Nelson (1973) the extraction of salt from the brine table underlying the Qa Azraq formed one of the most important local industries during the 20th century CE. Moreover, fat extracted from gazelle limb bones could have been mixed with dried strips of meat and kept safe for prolonged periods of time (Stopp, 2002). Given the antiquity of the site and the absence of pottery, an interesting question emerges: Where did Epipalaeolithic foragers store the preserved foodstuffs? The ethnographic literature provides a broad range of options that might have been available during the Epipalaeolithic; these include containers made from perishable material (Peña-Chocarro et al., 2015) such as animal skin, straw, cordage and plant fibers, air-tight vessels made from animal bladder or oesophagus, soft tissues or even tightly packed rawhide bags (Manne, 2014: 221; Wissler, 1910). Preserved foodstuffs, including meat mixed with fat could have also been packed in tortoise carapaces and the refitted tortoise carapace found in Locus 034 might have served as a food storage box (Spyrou, 2015: 262).

The empirical evidence for meat preservation through drying at Kharaneh IV broadens our view of the potential range of food preservation and storage capabilities and consequent patterns of site occupancy and mobility in pre-agricultural societies. Meat preservation and storage at Kharaneh IV might be seen as an adaptive response to the relatively extreme seasonal variations of resources of the eastern Jordan steppes, ensuring that hunter-gatherers potentially portable supplies into the arid seasons (ie. summer), when grasses would have died back, vegetation restricted, and when – as predicted through gazelle dental isotope analyses from the site (Henton et al., 2017, 2018) – herds may have been more widely dispersed across the landscape than in lusher winter/spring seasons.

Storage practices at the site could also have social incentives, including communal feasting events, trade and exchange with other communities with which Kharaneh IV foragers were interacting, allowing greater levels of mobility while also providing opportunities for more sedentary lifestyles.

7. Conclusion

While there is much known about Epipalaeolithic hunting/trapping strategies in the southern Levant, the literature is silent regarding preservation and storage of animal resources. This gap in research primarily relates to taphonomic issues and the challenges of recognizing storage in the archaeological record. The main problem lies with the fact that storage generally involves perishable food placed in perishable containers (for animal foods at least), or utilises structures which are often scattered over the landscape, away from excavated sites where archaeologists stand a chance of finding them (Morgan, 2012). The prime goal of this paper is to increase awareness of this underexplored yet key topic for the Levantine Epipalaeolithic research, in terms of understanding subsistence practices, mobility, seasonality and settlement adaptations, and to demonstrate a methodological approach for detecting animal carcass-product storage practices in prehistory, opening an important avenue for further research.

Focusing on Kharaneh IV, a hunter-gatherer aggregation site in the Azraq Basin, Jordan, we have employed zooarchaeological and taphonomic data and contextual analyses of faunal skeletal elements from stratified deposits around a series of postholes, combined with relevant ethnographic information, to provide convincing evidence that meat preservation through drying was practiced at the site. The tentative interpretations of the postholes found in the Middle Epipalaeolithic levels of Kharaneh IV are suggestions based on comparative

ethnographic records (Binford, 1978; Friesen, 2001), since nothing similar has yet been identified in other prehistoric contexts in the Middle East.

Food preservation and storage of animal resources were not exclusive adaptations at Kharaneh IV but undoubtedly a common practice resulting from shared ecological knowledge during the Epipalaeolithic and likely earlier. In other words, the absence of evidence for meat preservation and storage from other Levantine sites seems to be an artefact of preservation and lack of systematic research concerning this fundamentally important topic.

For zooarchaeology, meat preservation and storage are important aspects for consideration since different preservation and storage techniques can lead to particular bone modification signatures – including skeletal part representation, butchery and fragmentation evidence, the extent (or lack of) carnivore attrition visible on bone, and burning evidence – all which needs to explore contextually. No doubt zooarchaeological methods can and will be refined for recognizing meat and other animal product preservation in the prehistoric record; this study represents one step toward that overall goal.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jaa.2019.02.004.

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